AN ASSESSMENT AND PROPOSED CLASSIFICATION OF CURRENT CONSTUCTION AND POST CONSTRUCTION STRUCTURAL BEST MANAGEMENT PRACTICES (BMPs)

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Abstract

The more stringent NPDES Phase II Storm Water regulations of the US Environmental Protection Agency (EPA) Clean Water Act are set to take effect in March of 2003. This legislation will require a growing number of municipalities, construction and industrial sites to develop, implement, and enforce storm water management programs to reduce the discharge of pollutants to the "maximum extent practicable" to protect water quality. Compliance with these enhanced EPA policies will lead to an inevitable increase in the development and use of sediment control measures and other storm water treatment Best Management Practices (BMPs).

During the past few years a growing number of sediment control and storm water treatment devices have entered the market. Unlike products or techniques designed only to limit or control erosion, these devices are intended to help filter, capture and contain sediment transport (the by-product of erosion) and other pollutants that are generated and transported during and after construction related activities. As with many emerging technologies, confusion may develop as appropriate applications for specific products or families of products are not yet clearly developed and/or sufficiently defined. This may result in end-users lacking clear direction on the proper selection and/or use of these devices for specific applications.

This paper will propose a comprehensive and logical system to organize into classifications the growing range of BMPs and techniques for specific prescribed functions or applications while integrating these applications into the pre-construction, construction and post-construction phases of land disturbing, site development activities. This classification system is intended to assist planners, contractors, designers, and regulatory agencies so that they may have a better understanding of BMP selection based on application needs for protecting the environment from the negative impacts of construction and post-construction storm

water runoff. It is hoped that these proposed classifications combined with increased field experience will evolve into practical and cost-effective methods of BMP selection for an increasingly diverse array of storm water treatment measures and applications.

Background

With the application deadline for National Pollutant Discharge Elimination System (NPDES) Phase II Storm Water Permit coverage rapidly approaching storm water professionals, contractors, and end-users will need a systematic and logical method for establishing techniques, management tools and classifications of Best Management Practices (BMPs) to be integrated into the construction phase for storm water management. The new requirements of Phase II lower the threshold for permit coverage for construction activities from 5 acres to 1 acre. In addition, regulations affecting municipalities and public entities with Municipal Separate Storm Sewer Systems (MS4s), within urbanized areas may also result in additional local construction requirements.

Regulators have two primary concerns that will underlie storm water requirements in the site plan approval processes. These are the control of water quantity and quality both during and after the construction phase. Water quantity outputs from sites will generally be limited to pre-development levels. Water quality issues will focus on the reduction of contaminants from the runoff prior to its discharge from the site. Sediment has been recognized by EPA and others as the most prevalent constituent of concern for US receiving waters. (Northcutt 1992 and Theisen 1991). It will be the focus of most of the BMPs discussed in this paper. Other problematic constituents include nutrients, metals, hydrocarbons and other organic compounds, bacteria, and others, and each site must be analyzed to determine specific application needs. Understanding what types of structural BMPs are available and how they interact with one another will help provide guidance in selecting the right mix for a specific site.

A major consideration to be determined is how maintenance will be assured and performed over the long run. Thus, planners need to think of BMP selection as a revolving process of Installation, Inspection, Maintenance and Enforcement (I^2ME). While this paper focuses on the selection aspects, decision maker need to consider the latter three components to insure quality-based selections of appropriate BMPs. Many techniques and technologies may involve lower upfront costs, but maintenance costs over time must be factored into the equation.

In order to ensure that the maximum benefit is achieved planners will need to evaluate various BMPs in the pre-construction, construction, and post-construction phases to ensure their plans are approved in a timely and cost-effective manner.

Phases of Construction

Pre-Construction

The pre-construction phase will require a careful analysis of the specific site. The first step will be to gain a clear understanding of what storm water controls are required by state regulations, local ordinances and site plan approval processes. Nearly all will require controls during the construction phase to control sediment and to limit runoff from the site in order to ensure minimum impacts on downstream receiving waters. The primary construction concern will be sediment control and a wide range of both temporary and permanent BMPs will be needed. Each application must be examined to determine site specific needs for laying out the sequence of selecting both temporary and permanent BMP's. This sequence is commonly referred to as the "treatment train" and a clear understanding of all available options is critical for a successful site plan.

According to EPA's Preliminary Data Summary of Urban Storm Water Best Management Practices an urban storm water BMP is a "technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner." Many people only have a vague understanding of the range of BMPs available, and with ongoing research, new BMPs are constantly emerging. In fact, the term 'Best Management Practices' would be more accurately phrased as 'B*etter* Management Practices' because what is 'best' varies with each situation

In devising an effective organization of BMPs to assist planner and end users in the selection process several factors must be considered. First, the proposed land use of a project must be determined. These possible uses include industrial, commercial, residential, and streets and highways. For each of these various uses the specific site application needs must be determined. Consideration should be given to whether the project is new or re-development. A detail review of receiving water concerns along with an analysis of the potential pollutants of concern that might be generated on the site and that could have a negative impact also needs to be completed prior to BMP selection.

Once a review of the land use and receiving water concerns is completed then a review of the appropriate BMP options can be evaluated. The wide range of BMP options can be organized into several classifications by determining what the BMP can accomplish. Many are designed to control erosion and contain sediment transport. This is particularly important in the active construction phase where site stabilization has not yet occurred. Other BMPs deal with controlling the quantity of run-off that will occur as a result of both construction activities and post-construction changes in flow that will occur as a result of increased imperviousness on the completed site. Again, this will be factor of the intended land use. Finally, many BMPs are utilized for treatment of run-off to reduce pollutants that are generated during the construction and post-construction phases.

Many quality and quantity issues can be resolved through efficient site designs that incorporate practices that prevent the transport of water and pollutants from increasing as a result of development. These preventive measures can greatly reduce the need for reactive designs and technologies that are needed to contain water and remove pollutants of concern. It is, however, beyond the scope of this paper to analyze Better Site Designs. Instead the focus will be on the organization of structural BMPs and related Storm Water Treatment Devices (SWTDs). SWTDs are structural or non-structural BMPs that positively impact Storm Water quality before, during or after construction or construction related, land-disturbing activities. SWTDs may be temporary or permanent depending upon their desired application or function.

Structural BMPs can be divided into three primary types. These include Vegetative Techniques and Open Space Designs, Designed Structures, and Manufactured Technologies. The following chart lays out a proposed organization of BMPs based on type and Function.

Classification of Structural BMPs

Vegetative Techniques and Open Space Designs

- Constructed Wetlands
- Bio-retention Systems
- Swales

- Filter Strips
- Rain Gardens
- Green Roofs

Structural Designs

- Porous Pavement
- Below Surface Chamber Systems
- Infiltration Basins/Trenches
- Drywells
- Detention Basins
- Oversized Pipes
- Retention Ponds (Wet Ponds)
- Design-Sand Filters

Manufactured or "Proprietary" Devices

- Hydrodynamic Separator Systems
- Filtration Systems
  - In-Line Filtration Systems
  - Catch Basin Inserts – Long Term/Short Term
  - Exterior Treatments

  Storm Water Underground Storage Tanks
- Fabricated Underground Piping Systems

A broad overview of various BMP types is provided below in the post-construction phase section to help clarify the assessment and selection process for meeting construction and post-construction requirements

Active Construction

Sediment-Containment Systems

The role of sediment control systems is to create conditions for sedimentation, allowing for the settlement of soil particles that are held in suspension. When soil-particle transport mechanisms flow at slow rates, particles may settle out of suspension. How deposition occurs may depend upon several parameters.

Sediment-control systems are generally hydraulic controls that function by modifying the storm-runoff hydrograph and slowing water velocities. This allows for the deposition of suspended particles by gravity. Some of the more common names for these structures are sediment basins, sediment ponds and sediment traps. When designed correctly, sediment-containment systems should provide containment storage volume sufficient to handle incoming waters, create uniform flow zones within the containment storage volume for deposition of suspended particles and discharge water at a controlled rate.

When all runoff waters are captured, efficiency of the containment system is near 100%. However, the feasibility of retaining all runoff waters from a construction site is usually impossible since large containment areas and volumes are required. In addition, evaporation and infiltration might not be sufficient to drain the system before the next storm event occurs, which may cause flooding problems. Finally, retained waters may hamper maintenance of the system since removal of captured sediments becomes more complicated with the presence of water.

Due to the above concerns, rather than attempting to retain all runoff waters, a containment system should provide sufficient volume for capturing suspended particles while allowing discharge to occur. This provides the advantage of detaining incoming runoff to control the discharge of suspended particles while not requiring large areas to store runoff waters. Flooding problems from sequential storm events are reduced since contained waters will usually be drained from the system between events. Finally, frequent maintenance is facilitated because the sediments do not remain saturated with water.

If detention of runoff from construction sites is to be effective in removing suspended particles, contained waters must remain long enough for deposition of suspended particles within the system. Since outflow from the system will occur, 100% reduction of all incoming suspended particles will not be possible. However, high efficiencies can occur for sediment-containment systems developed for design-sized particles. (Fifield, 1995 and 1996.)

Sediment-containment systems may be characterized using the following assumptions. Goldman (1986) defined a structure that treats runoff from 2.0 ha (5.0 ac) or less as a “sediment trap.” When the contributing area to the structure exceeds 2.0 ha, then a “sediment basin” is used. Both structures are “sediment-containment systems” that function on the principles discussed previously.

EPA has suggested that the design of any sediment-containment system be based upon capturing the volume of runoff resulting from a 2-year, 24-hour storm event (US EPA 1992 and 1998). The problem with considering only the volume from a contributing area is that it does not take into account the size of the particles generated by upstream eroding soils. Table 1 provides suggested definitions for sediment-containment systems.

Table - 1 - Defining Sediment-Containment Systems Using Particle Diameters (Fifield, 2001)

Sediment-Containment System Type	Design Particle Size
Type- 1 Sediment-Containment System	Design- Size Particle $\leq$ 0.045mm
Type- 2 Sediment-Containment System	0.045 mm < Design-Size Particle $\leq$ 0.14 mm
Type- 3 Sediment-Containment System	Design-Size Particle > 0.14 mm

Type- 1 Sediment-Containment Systems

A Type- 1 sediment-containment system will require development of a structure to capture the maximum possible number of medium silt and smaller suspended particles. Since particles of this size have low settling velocities, large storage volumes, long flow-path lengths, and controlled discharges are required. Type-1 systems are designed to have the highest possible net efficiency and are best represented by the traditional sediment basin and trap.

Type-2 Sediment-Containment Systems

The Type-2 sediment-containment system will capture suspended particles having higher settling velocities than particles requiring Type-1 structures. Consequently, smaller storage volumes and shorter flow-path lengths can be used. As with a Type-1 structure, these sediment control systems will also have controlled discharges. While their net effectiveness for the entrapment of all suspended solids may be low, Type-2 systems will still have a high apparent effectiveness.

Type-3 Sediment-Containment Systems

The least effective methods to control suspended particles in runoff waters are represented by Type-3 sediment-containment systems. These are not necessarily design structures, but are often temporary BMPs found on construction sites. Examples include straw or hay bales and silt-fence barriers, inlet control structures, and drainage ditch check structures.

Whenever significant runoff occurs, all Type-3 systems have very low net and apparent effectiveness to control suspended particles. However, when runoff quantity is low, the Type-3 sediment control systems can be effective in reducing suspended particles as long as they are continuously maintained.

The Effectiveness and use of Sediment-Containment Systems

Documentation on the effectiveness of containment systems for trapping suspended solids is limited, and there are conflicting opinions on their actual effectiveness. However, if properly designed, constructed, inspected, and maintained, containment systems are effective in trapping some sediment.

This discussion will focus on selected, man-made non-structural Type-3 sediment-containment systems that act as barriers or filters. Since their effectiveness is minimal for large runoff events, they do not require the detailed designs needed for Type-1 and Type-2 containment systems. These devices must be carefully installed and in conjunction with Type-1 and Type-2 systems to minimize downstream problems since their usefulness is generally limited to low volume flows from smaller storm events. As such, these systems are typically only used and installed during the pre- and active-construction phases of a project.

A barrier is any structure that obstructs or prevents the passage of water. If runoff cannot pass through a barrier, then water will either be contained or flow over the structure. Consequently, small sediment barriers may function as a Type-3 system or as a method to reduce flow velocity. Commonly used man-made barrier devices include silt fences, continuous geotextile-wrapped berms, turbidity barriers, and geosynthetic silt dikes.

Appropriate places to use sediment control barriers include:

- Along sections of a site perimeter
- Below disturbed areas subject to sheet and rill erosion
- Below the toe of exposed and erodible slopes
- Along the toe of stream and channel banks
- Low flow swales and ditches

- Around area drains or inlets located in a sump
- Turbidity barriers are used in low flow streams, tidal areas or lakes

Inappropriate places to use sediment control barriers include:

- Parallel to a contour when installed on a hillside
- In channels where concentrated flows occur, unless properly reinforced
- Upstream or downstream of culverts where concentrated flows occur
- In front of or around inlets where concentrated flows occur and sump conditions do not exist
- In continuously flowing streams or ephemeral channels

Other Type-3 devices designed to provide filtration include geotextile catch basin inserts, geosynthetic drainage and curb inlet filters, geotextile tubes, and geotextile filter bags. These materials allow water to flow through them while filtering or capturing sediment. Selection of the correct geotextile or fiber consistency will reduce the possibility of blinding or clogging of the device with excessive sediment. An example of a Type I geotextile catch basin insert is shown in Figure 1.

Appropriate places to use geosynthetic filters would be in front of or around gutters and drain inlets where *sump conditions exist* and areas of de-watering of detention/retention ponds or dredging of construction and/or industrial spoils.

Inappropriate places to use geosynthetic filters would include in front of or around inlets where concentrated flows occur and *sump conditions do not exist* in channels where concentrated flows occur or in continuously flowing streams or ephemeral channels.

Man-made geosynthetic Type-3 barriers and filters have numerous advantages over traditional sediment control practices derived from natural materials. They are normally easier to transport, install and maintain versus straw and hay bales or soil and rock structures. Manufacturing and fabrication consistencies enable performance of geosynthetic devices to be more predictable and generally superior to natural materials. In many cases these devices may be washed and reused which makes their usage highly cost effective versus using traditional practices or nothing at all. Thus the acceptance and usage of geosynthetic sediment- and erosion-control devices has increased dramatically over the past few years (Theisen, 1991, Theisen and Hunt, 2001).

Figure 1 – Example of Type 1 Geotextile Catch Basin Insert -- Siltsack® by ACF Environmental

Figure 2 – Example of Silt Fence Containing Sediment -- Geotex® by SI Geosolutions

Post-Construction

Structural BMP's are techniques that can be used to address flow quantity control and pollutant removal in wet weather runoff. These BMPs can include site-specific engineered designs as well as proprietary systems. The challenge with any attempt to organize or classify BMPs by type or function is that many fit into multiple categories. However, in the interest of clarity structural BMPs can be grouped into several subcategories by function that includes the following.

- Infiltration systems
- Detention systems
- Retention systems
- Vegetated systems
- Filtration systems
- Hydrodynamic separation systems

Infiltration Systems

Infiltration systems are designed primarily to reduce the quantity of storm water runoff from a particular site. Increasing urbanization and percentage of impervious surfaces has resulted in substantial increases of surface runoff, causing serious degradation of urban streams and the corresponding negative impacts on aquatic health BMPs for Phase II The use of infiltration techniques can reduce the amount of surface flow and direct the water back into the ground. Advantages of infiltration techniques include the recharging of groundwater supplies and the removal of certain pollutants such as sediments. Care must be exercised, however, in determining whether infiltration is best for a specific application, especially when groundwater is the source of drinking water in the area. Infiltration can result in groundwater contamination since soils that allow good infiltration also allow rapid migration of certain pollutants. In these situations, infiltration should not be used without effective pretreatment. Conversely, poorly permeable soils can prevent an infiltration system from functioning.

Infiltration techniques can be divided into several different classifications depending on site needs. Regardless of the classification a careful understanding of the soil type is necessary since certain soils, such as clays, are poor infiltration types. If the soil type is appropriate for infiltration then the next step in the evaluation is determining which method is most appropriate. A site with minimal land space would be a likely candidate for porous pavement, and sub-surface chamber systems that can store water below impervious surfaces and allow for slow infiltration after the end of a wet-weather event. Conversely, sites with sufficient space should utilize infiltration basins, vegetative practices, constructed wetlands and open space designs.

Detention Systems

These BMPs are designed to temporarily hold storm water runoff for gradual release into receiving waters. Detention systems are used primarily to reduce peak discharges to prevent flooding, stream bank erosion, and channel alterations. Straight up Detention systems are generally not very effective for removing pollutants unless combined with other BMPs. Many detention systems incorporate characteristics normally utilized with retention ponds, such as permanent pools, to prevent subsequent scouring. Examples of detention systems include detention basins, underground tanks, oversized pipes, and fabricated underground high-density polyethylene piping systems such as Storm Compressor^{TM}.

Retention Systems

Retention systems are intended to capture and hold runoff from entering receiving waters. Because retention systems are designed for permanent containment of storm water, they can also be a good infiltration and or filtration BMP with the right conditions, thus providing both water-quantity and water-quality control. Retention systems can be in a variety of forms such as green roofs, but most retention systems are in the form of ponds or basins, (also commonly referred to as wet or detention basins) and when certain types of aquatic vegetation or aerators are added, the systems can actually provide further water treatment (see figure 3 below). As with all BMPs, regular maintenance is essential to maintain a healthy retention pond. Clay siltation can result in a substantial loss of infiltration, resulting in a sharp increase in overflow from the basin during wet-weather events. Without maintenance, retention ponds will eventually fill in and become ineffective. In addition, certain pollutants can become concentrated in the area, potentially requiring remediation.

Most storm water collection ponds are in fact combinations of retention and detention applications. While these ponds are designed to hold most flows they are usually equipped with some sort of overflow system to prevent flooding over their banks. These overflow systems are either reset in the middle or end of the ponds or a spillway of rip-rap, other coarse materials or vegetated turf reinforcement mats. When the runoff into the pond is from an impervious area with high vehicle traffic, post-treatment devices in the riser can provide initial management of floating oils and other toxins prior to discharge into the receiving waters.

Figure 3- Wet Pond (courtesy of Hydro Compliance Management, Inc.)

Vegetative Systems

Constructed Wetland Systems

Constructed wetlands are a very effective BMP for both pollutant removal and runoff storage (see figure 4 below). When properly designed, they incorporate the processes of sediment removal, microbial decomposition, and aquatic plant uptake. Sites for constructed wetlands must be carefully selected to ensure that sufficient waters are available in dry weather to sustain the wetlands. Areas with shallow groundwater levels are ideal. Heavy sediment loads can quickly degrade a constructed wetland. Pretreatment of sediment flows must be considered if this is the case. Generally, natural wetlands should be preserved and not used as a BMP because changing hydrology can significantly degrade a natural wetland.

Other wetland BMPs include wetland basins and channels. These BMPs do not necessarily require open waters and can instead be in the form of wetland meadows that have surface water only for short periods of time after precipitation events.

Figure 4 -Example of constructed wetland -- Tollgate Storm water Treatment Facility Lansing, Michigan (courtesy of Patrick Lindemann, Ingham County Drain Commissioner, and designer of the project)

Bio-retention and other Vegetated Systems

Bio-retention and vegetated systems, such as buffers and swales, are variations of infiltration and filtration systems. The media in these systems are actually natural vegetation and soil beds that allow ponding and gradual infiltration. The vegetation and underlying soils can filter a variety of pollutants from runoff. In addition, these systems can be used to reduce the quantity of flow. This category of BMP includes large bio-retention systems, swales, rain gardens, grass filter strips, and even green roofs. The use of these "natural" systems in site development can significantly cut down on surface runoff and reduce the need for other more costly structural BMPs (see figure 5 below).

Figure 5- Swale (courtesy of Hydro Compliance Management, Inc.)

Filtration Systems

Filtration systems are BMPs that use media to remove particulates from runoff. They are typically used when circumstances limit the use of other types of BMPs, such as where space is limited–particularly in a highly urbanized setting–or when it is necessary to capture particular industrial or commercial pollutants such as hydrocarbons or metals. In these circumstances, other BMPs might be cost-prohibitive or not as effective. Filtration devices can also work well as pretreatment systems for other types of BMPs. For example, infiltration systems that move water directly to ground aquifers might require pre-treatment for certain contaminants to maintain effective well-head protection of drinking-water supplies.

Filtration systems can be either designed into a site plan, such as sand filter systems, or be manufactured technologies such as catch-basin inserts or in-pipe systems (see figure 6 below for an example of a filtration device). Many different filtration media are available, such as sand, peat, absorbents, and activated carbon. The choice depends on the particular application.

When considering filtration systems, planners need to consider flow rates. As a result of the volume of water being moved in a wet-weather flow, filters generally need to focus on treating at least the first quarter inch of runoff and allow bypass for high-flow events. Filters should incorporate pre-settling sediment chambers to remove sediments that can clog the filters and reduce flow rates and effectiveness. An effective filtration system should be able to demonstrate removal efficiencies for specific contaminants. Again, as with all BMPs, regular maintenance is essential.

Proprietary filtration devices are catch-basin inserts or in-pipe designs that remove various pollutants. Effective designs should use non-leaching media, incorporate pre-filtration sediment removal chambers or other measures to reduce plugging, and be accessible for regular maintenance. In addition, filtration devices need to be designed with overflow bypasses to prevent flooding caused by high flow rates or plugging of the filters. A properly designed filtration system can be a useful device for urban hot-spot applications where a particular pollutant is being targeted. It also can be cost-effective where land use does not allow other economical BMP options. This is particularly true with existing sites in urban settings. Proprietary systems can be effective pre-treatment or post-treatment devices for infiltration systems and other BMPs.

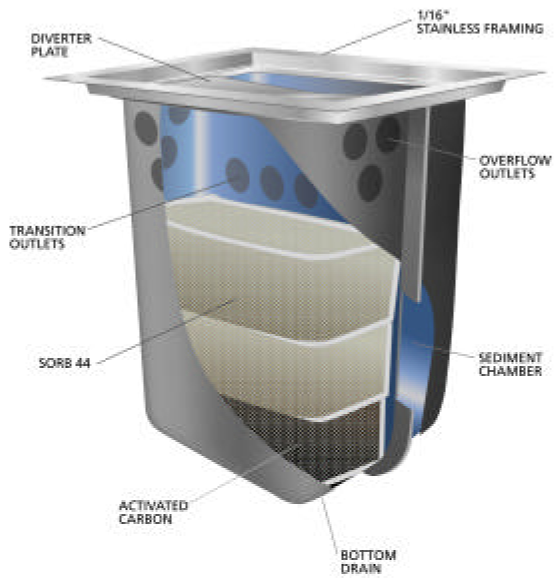

Figure 6- Example of Catch-Basin Filtration System – Hydro-Kleen™ Storm Water Filtration System (courtesy of Hydro Compliance Management, Inc.)

Hydrodynamic Separator Systems

These systems remove sediment, debris, and surface oils and grease through various hydrodynamic designs. Effective separator systems trap and separate pollutants to prevent them from being reintroduced into runoff, which can result from "scouring" or other actions prompted by the powerful energies created from heavy volumes of storm water runoff. Effective systems have protective zones for pollutant storage to prevent re-suspension or washout of contaminants and stabilize the flow regime to minimize turbulence.

Systems with stabilized rotary flow regimes tend to have smaller footprints than conventional gravity separators.

Functions of Storm Water Treatment Devices

SWTDs may be "proactive" or "reactive" in their approach or application. Examples of proactive SWTDs include erosion control practices, green roofs, vegetative filter strips, or rain barrels. Reactive techniques might employ sediment control practices, in-line treatment devices, sedimentation ponds, and detention/retention systems.

Basic functions of SWTDs may be grouped into five major categories. These are Sediment Containment, Filtration, Separation, Infiltration, and Underground Detention. Again, it is beyond the scope of this paper to describe and classify all the BMPs that may be used to fulfill these functions. Various manufactured SWTDs may be grouped by primary function as shown below.

Basic Functions of Storm Water Treatment Devices

- Sediment Containment
- Filtration
- Separation
- Infiltration
- Underground Detention

It is beyond the scope of this paper to describe and classify any and all BMPs or SWTDs that may be used to fulfill these functions. This paper, however, does describe various man-made SWTDs may be grouped by primary function as shown below.

Sediment-Containment Devices (SCDs)

- Silt Fences (SF)
- Continuous Berms (CB)
- Wattles (W)
- Drain Inlet Barriers (DIB)
- Channel Silt Dikes (CSD)
- Turbidity Barriers (TB)
- Geotextile Filter Bags (GFB)
- Geotextile Tubes (GTT)

Filtration Devices (FDs)

- Catch Basin Inserts (CBI)
    - Type 1 –Geotextile Filtration Systems (GFS)
    - Type II – Multi-Chamber Permanent Structures (MPS)
- Curb Inlet Filters (CIF)
    - Type 1 – Exterior - Geotextile Filtration Systems (GFS)
    - Type II – Interior - Multi-Chamber Interior Filtration Systems (MIF)

Separation Devices (SDs)

- Hydrodynamic Separation Devices (HSD)

Infiltration Devices (IDs)

- Infiltration Chamber Systems (ICS)

Detention Devices (DDs)

- Underground Piping Systems (UPS)

Once the function required of a SWTD has been determined, it is then time to consider when and where it should be employed. These two considerations are as important as the selection of the correct SWTD to be used. Failure to properly install a SWTD in the correct location or sequence of a land-disturbing activity may result in failure or compromised performance.

Once the application or function and appropriate construction phase of the required storm water treatments have been determined, these parameters may be coupled to facilitate selection of the most appropriate SWTD. Table 2 presents a matrix that combines function with construction phases for identifying potential SWTDs for selection consideration.

Table 2 – Function and Typical Construction Phase(s) for Application of Manufactured Storm Water Treatment Devices

Function	**Construction Phase**		
	Pre-Construction	**Active Construction**	**Post-Construction**
Sediment-Containment	SF, CB, TB	SF, CB, CBI, DIB, CIF, CSD, TB, GFB, GTT	CBI, CIF, HSD,
Filtration		CBI, CIF, GFB, GTT	GFB, GTT, HSD
Separation			HSD
Infiltration			ICS
Detention			UPS

Finally, where to use a SWTD must be considered. Again, it is beyond the scope of this paper to present specific site locations for the vast potential variances of SWTD applications. Good discussions for placement of several of these materials during active construction may be found in publications by Fifield as well as in EPA publications. Table 3 below presents a matrix coupling site location with the various construction phases. Combining Tables 2 and 3 may help end users to make informed decisions when considering SWTDs for various functions, construction phases and site locations.

Table 3 – Site Location and Typical Phase(s) of Construction for Application of Manufactured Storm Water Treatment Devices

Site Location	Construction Phase		
	Pre-Construction	**Active Construction**	**Post-Construction**
Perimeter	SF, CB	SF, CB	
Catch Basin Inlet, Curb Inlet		CBI – Type 1 & II, DIB, CIF, HSD	CBI – Type II, CIF, HSD,
Channel		CSD	
Slopes	SF, CB, W	SF, CB, W	
Waterway	TB	GTT	GTT
Sediment Basin/Trap		GFB, GTT	
Below Impervious Surfaces			ICS UPS

Conclusion

In order to insure that regulators, planners, engineers and contractors have a clear picture of what techniques and measures can be utilized in the various construction phases for proper BMP management, a solid understanding of the options is essential. By classifying the various sediment controls and post-construction BMPs into proper applications, storm water professionals are far more likely to develop efficient yet cost-effective storm water plans for specific projects. The result will be cleaner water and a more satisfied general public. A thorough understanding of the Installation, Inspection, Maintenance, and Enforcement requirements will also result in a more comprehensive and realistic cost analysis of the project.

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